

AD-A075 161

HARRY DIAMOND LABS ADELPHI MD
A NUMERICAL CONTROL FACILITY FOR SEMIAUTOMATIC WIRE-WRAPPING AN--ETC(U)
AUG 79 A LEE, R W HIN
HDL-TM-79-20

F/G 9/5

UNCLASSIFIED

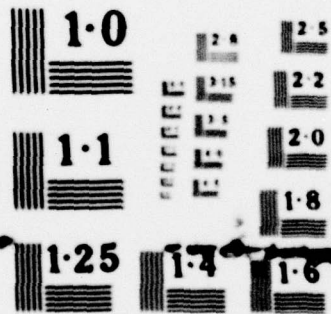
NL

1 OF 1
AD-A075161



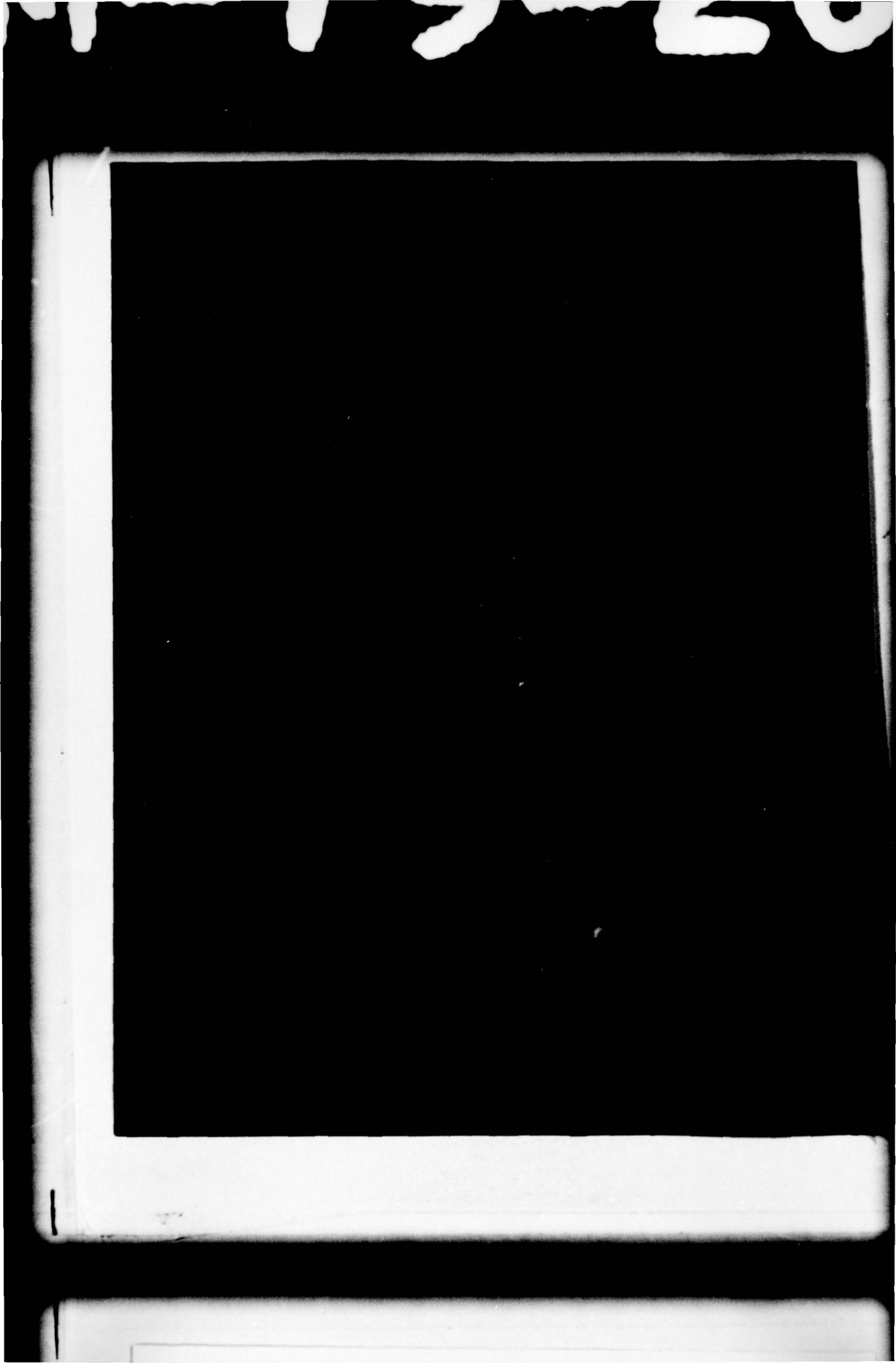
END
DATE
FILMED

11-79
DDC



NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

ADA075161



UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER HDL-TM-79-20	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A Numerical Control Facility for Semiautomatic Wire-Wrapping and Verification	5. TYPE OF REPORT & PERIOD COVERED Technical Memorandum	
7. AUTHOR(s) Albert/Lee and Rosalie W./Hine	6. CONTRACT OR GRANT NUMBER(s)	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Harry Diamond Laboratories 2800 Powder Mill Road Adelphi, MD 20783	10. PROGRAM ELEMENT, PROJECT, TASK AREA & REPORT NUMBER 1245	
11. CONTROLLING OFFICE NAME AND ADDRESS Commander U.S. Army Electronics Command Ft Monmouth, NJ 07703	12. REPORT DATE August 1979	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	13. NUMBER OF PAGES 43	
	15. SECURITY CLASS (of this report) UNCLASSIFIED	
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES HDL project: 873782 DRCMS code: 5297.02.98320		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Wire-wrap Verification of wire-wrap Numerical control		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report describes the procedures for processing information to be used by a paper-tape-controlled semiautomatic wire-wrap machine. Details concerning computer start-up and wire-wrap machine setup are explained in separate instruction sets. The instructions are presented step by step, to minimize training time for inexperienced operators.		

DD FORM 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

1

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

163 050

50

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

2 A wire-wrap verification option is also described, which provides a means to perform quick, comprehensive checks of wire-wrap connections. K

UNCLASSIFIED

CONTENTS

	Page
1. INTRODUCTION.....	5
2. N/C TAPE PREPARATION.....	7
3. VERIFICATION OPTION.....	13
3.1 Description.....	13
3.2 Current Modifications.....	16
4. WIRING OPTIONS.....	16
5. CONCLUDING REMARKS.....	17
DISTRIBUTION.....	43

APPENDICES

A.--COMPUTER START-UP PROCEDURES.....	19
B.--ASSEMBLING AND LOADING AN XYDIM PROGRAM.....	25
C.--SETUP AND USE OF KEYTRONICS WAND IN WIRE-WRAP.....	29
D.--NUMERICAL CONTROL TAPE PUNCHING.....	31
E.--NUMERICAL CONTROL WIRE-WRAP MACHINE SETUP.....	33
F.--HEWLETT PACKARD (HP 2100A) WIRE-WRAP SOFTWARE.....	39

FIGURES

1. Wire-wrapped posts.....	5
2. Semiautomatic wire-wrap machine.....	6
3. Operational amplifier.....	8
4. Typical wire-wrap board (one-section socket side).....	8
5. Wire-wrap board (entire board).....	9
6. Example of XYDIM subroutine.....	10
7. Editing commands as displayed on CRT.....	11
8. Single-wire nets.....	13
9. Wired nets daisy-chained together.....	13
10. Square-routing.....	16
11. Z-routing.....	16

Accession For	
NTIS GSA&I	<input checked="" type="checkbox"/>
DOC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or special
A	I

1. INTRODUCTION

The fabrication of electronic systems is highly dependent upon the method of interconnecting circuit components, which may be discrete parts or integrated circuits. The two major methods for providing electrical interconnections for discrete parts are printed-wiring boards and wire-wrapping. Although printed-wiring has an advantage for high-production and low-density applications the use of wire-wrapping for short-run digital circuits of high complexity is commonplace.

Wire-wrapping is a process for interconnecting a large number of electronic components to form circuit functions. The assembly consists of a board with component sockets on one side, and corresponding wire-wrap posts on the other. The components are connected by wire-wrapping the posts. This technique involves tightly wrapping a prestripped wire around a square post. The wrap is sufficiently tight to cause each edge of the post to penetrate the wire and form a gas-tight cold-weld. A proper wrap will circle the post six times, hence effecting the equivalent of 24 cold-weld joints (fig. 1).

The completed process usually yields a multitude of wires. Post designations, which are necessary to differentiate between various posts, are often obscured in this dense nest of wires. Obscured designations can lead to the wrapping of incorrect posts. Although care may be taken to wrap correct posts only, the wrapping of high-density boards is subject to error, and becomes time-consuming. To minimize wiring errors and speed up the process, semiautomatic wire-wrapping machines (fig. 2) are often used. One such machine is in use at the Harry Diamond Laboratories (HDL). The wire-wrapping machine and an associated computer make up this semiautomatic wire-wrapping system. The

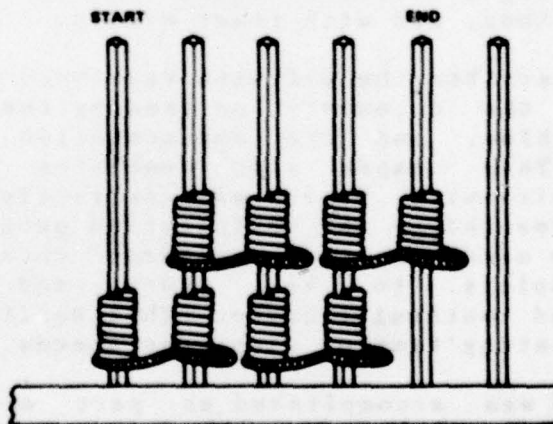


Figure 1. Wire-wrapped posts.

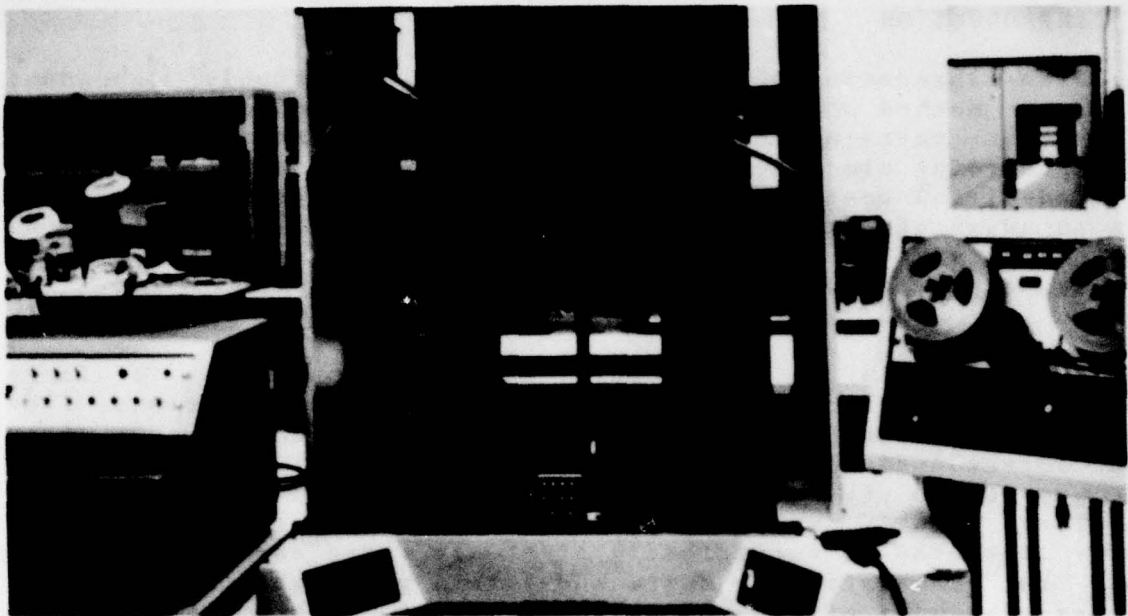


Figure 2. Semiautomatic wire-wrap machine.

computer portion of the system takes, as input, a list of post locations and their corresponding assigned node-names, and provides, as output, a numerical-control (N/C) paper tape. The wire-wrapping machine processes information found on this N/C tape. The final result is a machine movement to (1) locate the correct starting post, (2) provide the correct length of stripped wire, and (3) locate the correct ending post. This process is then repeated for all remaining wires. The actual wrapping of the wire around the post is done manually by the machine operator. The system, using this basic method, can perform wire-wrapping at rates at least 7 to 10 times faster than totally manual methods, and with fewer errors.

This paper describes the software developed to create the N/C drive tapes, the documentation used by the operator of the wire-wrapping machine, and the documentation delivered to the customer. This paper also describes an algorithm to verify that the wire-wrap board was correctly wired. This algorithm is implemented by the verification program producing a test tape which is used on the wire-wrap machine. The wire-wrap machine points to posts and the operator performs visual and continuity tests. This verification process greatly reduces testing time of wire-wrap boards.

This project was accomplished as part of the U.S. Army manufacturing technology program. The primary objective of this program is to develop, on a timely basis, manufacturing processes, techniques, and equipment for use in the production of Army material.

This report includes appendices which give procedures used to activate various phases of the HDL wire-wrap facility. Appendix A gives computer start-up procedures, appendix B gives procedures for assembling and loading an XYDIM program, appendix C describes the setup and use of the Keytronics wand, appendix D describes N/C tape punching, appendix E describes the N/C wire-wrap machine setup, and appendix F describes the wire-wrap software.

2. N/C TAPE PREPARATION

N/C tape preparation requires several steps. The individual procedures are

1. data conversion,
2. data input,
3. data sort, and
4. tape punch.

Data conversion is the process of translating schematic information on drawings to a computer-recognizable wire-list. This wire-list is a coded description of every post to be wire-wrapped. For a particular post, the coded description consists of two 7-character words. The first word is a mnemonic describing the electrical signal (B+, GRD, . . .etc) to be wire-wrapped to the particular post. The second word is a mnemonic describing the physical location of the post.

Data conversion is achieved in two steps:

1. Assign signal mnemonics to all posts to be electrically interconnected by wire-wrapping.
2. Assign location mnemonics to all posts to be electrically interconnected by wire-wrapping.

For example, figure 3 depicts an operational amplifier and its corresponding signal mnemonics (B+, IN+, IN-, OUT, GRD), location mnemonic (D10), and component pinouts (1, 2, 3, 4, 5). The "D10" location mnemonic refers to socket location 10 and section code D of the wire-wrap board (fig. 4).

The signal and location mnemonics and pinouts combine to generate half the wire-list, as shown below.

Signal mnemonic	Component location mnemonic
IN + X X X X	D 1 0 X X 0 2
IN - X X X X	D 1 0 X X 0 3
OUT X X X X	D 1 0 X X 0 4
B + X X X X X	D 1 0 X X 0 1
GRD X X X X	D 1 0 X X 0 5

NOTE: The previous wire-list (half) represents the beginning of five wire-wrap wires; the ends of these wires make up the remaining five entries in the wire-list. In general, a wire-list can contain the beginning and ending wire-wrap connections for hundreds of components. The data conversion step is concluded when a wire list is created to describe all wire-wrap terminations.

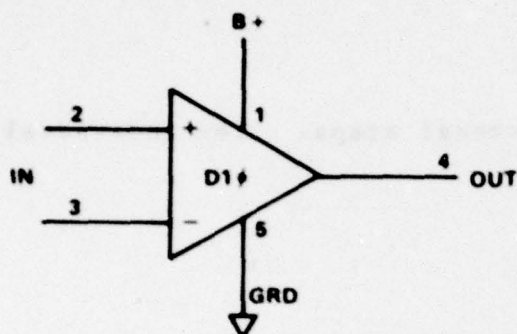


Figure 3. Operational amplifier.

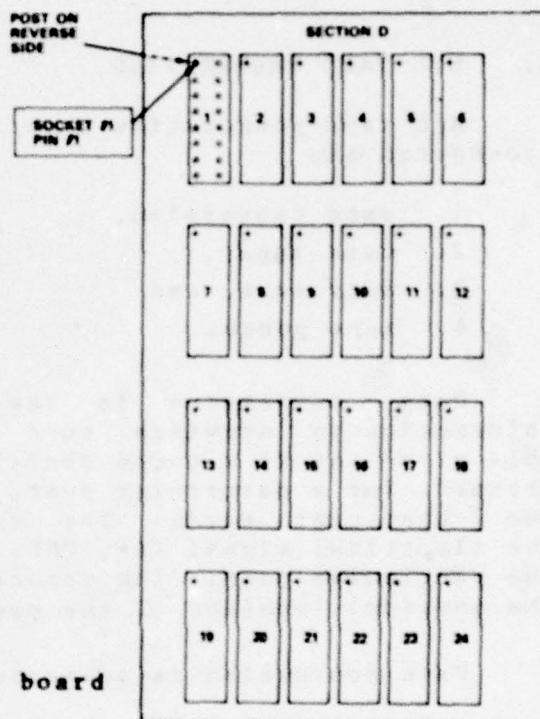


Figure 4. Typical wire-wrap board (one-section socket side).

The next step, data input, involves the transfer of wire-list information from a written form to the computer. Because of the uniqueness of any wire list and corresponding wire-wrap board, a computer program is required to properly interpret the wire-wrap list for the main WRAPS program. The wire-list interpreter is a subroutine called XYDIM. This subroutine is a FORTRAN algorithm for calculating the X and Y coordinates of any post (of a particular board) in the wire-list. This routine is required because the wire-wrap machine requires X,Y positional data, but the data lists are in alphanumeric positional data. The XYDIM program relates the two types of data. All calculated coordinates are referenced to a board origin. The origin of choice is normally the uppermost post nearest the left or right corner of the board. The choice of left or right is decided by the orientation of component sockets. For example, the origin of the wire-wrap board shown in figure 5 is the right uppermost post (section A, socket 1, post 1). The XYDIM subroutine to describe the example wire-wrap board is listed in figure 6.

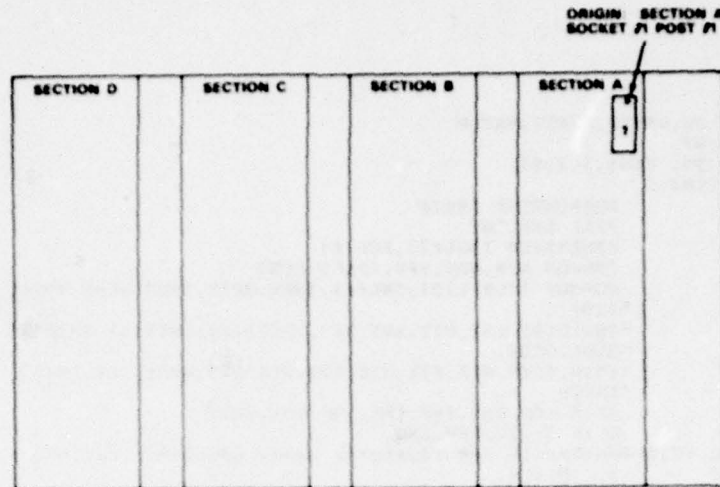


Figure 5. Wire-wrap board (entire board).

The numbers along the left margin in figure 6 refer to the line numbers. Lines 1 to 4 are compiler control statements, lines 5 to 52 make up XYDIM for the board in figure 4, and lines 53 to 59 are more compiler control statements.

Information for loading and assembling the XYDIM program is found in appendix B.

After the loading and assembling of the XYDIM subroutine, the data input process starts with a session in which computer and user exchange pertinent data. During this session, the computer requests header data and wire-list data. Header data include

- customer name,
- wire-list,
- revision codes, and
- wire-wrap board characteristics.

The computer displays data requests on the CRT, then pauses, waiting until the operator responds with the proper input at the terminal. After all header data are entered, the computer requests wire-list data and displays a series of X's to represent the correct input format:

```
X X X X X X X   X X X X X X X
[X]
```

```
Blinking Cursor = [X]
```



```

0001      :PU,WRAPS,PART1,PXYDM
0002      :PP
0003      :PR,FTN4,5,1.99
0004      :FTN4,L
0005          SUBROUTINE XYDIM
0006          REAL LWX,LWY
0007          DIMENSION INOL(2),KCD(6)
0008          COMMON NIN,NOT,IPP,IPAGE,LCNT
0009          COMMON ICUST(20),IWL(6),IREV,GRID,IANG,WLMN,STPLT
0010          *ISW11,
0011          *ISWLS(5),LWX,MIX,LWY,HIY,INCRD(80),NET(7),NPIN(7)
0012          *OLDL,OLDX,
0013          *XDIM,YDIM,SIX,SIY,S2X,S2Y,PIX,PIY,WPLT,IBZ,ISW12,
0014          *INSTR,
0015          DATA KCD/1HA,1HB,1HC,1HD,1HE,1HF/
0016          DATA IV,IG/1HV,1HG/
0017      C THIS ROUTINE IS FOR (customer name) GROUPING SECTIONS A
0018      C      B,C,D,E,F.
0019          XDIM=0
0020          YDIM=0
0021          IF(INCRD(49).NE.KCD(1))GOTO 10
0022          GOTO 17
0023      10      IF(INCRD(49).NE.KCD(2))GOTO 11
0024          XDIM=XDIM-2.5
0025          GOTO 17
0026      11      IF(INCRD(49).NE.KCD(3))GOTO 12
0027          XDIM=XDIM-5.3
0028          GOTO 17
0029      12      IF(INCRD(49).NE.KCD(4))GOTO 13
0030          XDIM=XDIM-7.8
0031          GOTO 17
0032      13      IF(INCRD(49).NE.KCD(5))GOTO 14
0033          XDIM=XDIM-10.6
0034          GOTO 17
0035      14      IF(INCRD(49).NE.KCD(6))GOTO 17
0036          XDIM=XDIM-13.1
0037      17      CALL MOVE(INCRD,50.51,INOL,1)
0038          CALL TRANS(INOL,1,2,ICNUM)
0039          IF(ICNUM.GT.6)GOTO 25
0040          XDIM=XDIM-((ICNUM-1)*.4)
0041          GOTO 50
0042      25      IF(ICNUM.GT.12) GOTO 35
0043          YDIM=YDIM+1.35
0044          XDIM=XDIM-((ICNUM-7)*.4)
0045          GOTO 50
0046      35      YDIM=YDIM+2.55
0047          XDIM=XDIM-((ICNUM-13)*.4)
0048      50      CALL MOVE(INCRD,54.55,INOL,1)
0049          CALL TRANS(INOL,1,2,ICPIN)
0050          IF(ICPIN.GT.8) GOTO 75
0051          YDIM=YDIM+((ICPIN-)*.1)
0052          GOTO 100
0053      75      XDIM=XDIM-.3
0054          YDIM=YDIM+((16-ICPIN)*.1)
0055      100      RETURN
0056          END
0057          ENDS
0058      :ST,P,PXYDM
0059      :CL
0060      :PP,LOADR,2,1
0061      :WRAP,PNN1,PXYDM
0062      /E
0063      :PU,PXYDM
0064      :TY

```

Figure 6. Example of XYDIM subroutine.

Starting at the leftmost cursor position, wire-list data are typed beneath the X's. Signal mnemonics are typed beneath the first block of X's; location mnemonics are typed beneath the last block of X's. Wire-list data can be transferred to the computer by

1. CRT terminal (keyboard),
2. Keytronics wand (optical scanning), or
3. paper tape.

Of the three methods, the CRT terminal is most useful for entering header data, editing all data, and passing command instructions to the computer. The second input method uses the Keytronics wand, a hand-held optical scanner capable of reading specially pretyped information. The scanner is the optimum method for transferring wire-list data to a computer. (Instructions for using the Keytronics wand are given in appendix C.) The last input method, paper tape, is most ideally suited for initiating the wire-wrap programs and compiling XYDIM algorithms.

The data input session is finished when all header and wire-list data have been passed to the computer file.

Typed or scanned data may include errors, so it is reasonable to include an editing session before performing any data processing. The editing session begins with a computer-generated list of wire-wrap data. As the data are printed on the system line printer, each data element is assigned a "line number." This number is found in the rightmost column of the listing and is referenced whenever editing.

After printing the wire-wrap data file, the computer queries the user on whether or not editing is needed. If editing is required, a set of editing instructions (fig. 7) is displayed on the CRT terminal.

C,L,N

where

C = R for replace,
D for delete,
I for insert, and
E for end of edit,

L = the starting line for replacements and deletions or the line after which insertions are to be placed,

N = the number of lines to be replaced, deleted, or inserted (if N is not specified, it is set to 1).

Figure 7. Editing commands as displayed on CRT.

Up to now only the data input part of the WRAPS program has been active. After data editing is finished and the computer queries "CONTINUE TO PART 1,2 ?" the remaining portions of the WRAPS program may be started.

Part 1 of the WRAPS program checks, sorts, and codes each wire. Part 2 sorts and generates the N/C paper tape. Both parts provide documentation referring to wire length, wire location, and signal name. Also included is a check list of wire-wrap connections. This check list is a "from-to" printout which lists the beginning and ending wire posts.

The final procedure is the actual wire-wrapping, and this occurs at the wire-wrap station. The station consists of

1. an N/C paper-tape reader,
2. an N/C wire stripper,
3. an X-Y table/pointer, and
4. a pneumatic wire-wrap gun.

The normal sequence of events that occur during the wire-wrap termination process is as follows.

The N/C paper-tape reader processes a block of N/C data, and performs the following series of actions:

1. Strips a wire of specified length.
2. Points to the beginning post to be wrapped.
3. Lights direction indicators forewarning the operator of the direction of the next machine movement.
4. Pauses for operator to wrap the first wire (after the first wrap, the user frees the machine, allowing it to continue to the next post position).
5. Points to ending post (after the last wrap, the user frees the machine to process another block of N/C data).

This entire series of events continues until the last post is wire-wrapped. The wire-wrapping station setup procedures are described in appendix E.

In summary, the wire-wrapping system and computer provide a wrapping scheme with the following advantages over manual wrapping methods:

1. increased wiring rates,
2. minimal wiring errors,
3. repeatability,
4. specialized verification techniques, and
5. documentation.

3. VERIFICATION OPTION

3.1 Description

The semiautomatic wire-wrap machine normally points to every post designated in the wire-listing, but the possibility of operator error is still open because of board misalignment, pin skew, or improper wrapping techniques. To manually check the continuity of wiring for these boards is extremely expensive, time consuming, and usually not complete.

To offset the test time and provide a complete check for missing wires, extra wires, and improper wiring, a wire-wrap verification option is available. This option is realized as a computer program to generate two N/C test tapes.

The verification scheme works as follows. A given set of wire-wrapped posts contains two kinds of wired nets:

1. single-wire nets (start post, end post, and, in between, a single wire) and
2. multiwire nets (start post, end post, and, in between, multiple wire-post combinations).

If all the wrapped posts are correct, they can be modeled by many single-wire nets (let these nets be called pseudonets).

To simplify the testing concept, mentally unravel all the pseudonets and create a row of start and end posts (fig. 8).

First, all the starting posts are temporarily wired together, which is easily accomplished with any wire-wrap "daisy-chaining tool." The result of the first step is the intentional shorting of all wire nets together. The next step is to attach a continuity meter to the start of the daisy-chain shorting wire (fig. 9).

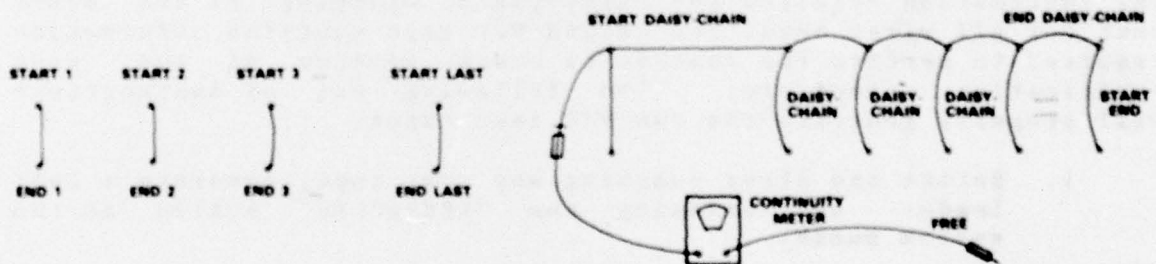


Figure 8. Single-wire nets. Figure 9. Wired nets daisy-chained together.

Before starting the actual testing which is the third step, note that the free end of the continuity meter can be used to verify the continuity from start to end of all the pseudonets. This can be done by merely showing that there is continuity between the daisy-chained wire and the end of every net. This check must precede the actual testing. The purpose of this step is to check that each net is attached to the daisy-chain.

The following verification procedure indicates whether any net is improperly wired.

1. Using the free end of the continuity meter and starting with the last end post, verify that a good electrical connection occurs. This checks for missing wires in the pseudonet.
2. Holding the free end of the continuity meter on the last end post, remove the daisy-chain wire from the last start post. The correct meter response is an open circuit. Any other indication implies that the net under test is shorted to another net. The discovery of any wire-wrap error should be immediately recorded.
3. Move the free end of the continuity meter to the next-to-last end post, and then verify continuity. Remove the daisy-chain wire from the next-to-last start post. Using the criteria established in step 2 above, verify that this net is not shorted to any other net.
4. Continue as in step 3, by moving the free end of the continuity tester to the next end post.
5. Repeat steps 3 and 4 until the daisy-chain wire is entirely removed from the board under test.

This verification scheme can effectively offset manual test times by using wrap data contained in the computer disc storage facility. These wrap data can be easily processed and will yield two N/C test tapes. The first N/C tape contains the information required for daisy-chain wrapping of the start post for all wired nets. The second N/C tape contains information required to perform the continuity check portion of the wrap verification procedure. The following set of instructions will properly generate the two N/C test tapes.

1. Before and after punching any test tape, generate a 2-ft leader by pressing the "FEEDHOLES" button on the system punch.
2. At the proper time the computer will make the following query on the CRT terminal:

PUNCH TEST TAPES?

3. Respond:

YES CrLf

(Note: CrLf--carriage return line feed)

4. Add the final 2-ft leader to the first test tape and properly mark the tape concerning customer and tape type (test-daisy-chain, test-continuity).
5. Add a 2-ft leader for next test tape.
6. Computer responds:

TYPE [CONTINUE] CrLf

7. Respond:

CONTINUE CrLf

8. After the second tape is punched, add a 2-ft leader and remove the tape. Properly mark the second test tape concerning tape type and customer name.

The following series of instructions refers to the proper application of test tapes.

1. After an entire back plane is wrapped, remove the N/C wrap tape and load the first test tape (daisy-chain).
2. Replace the normal wire-wrap tool with the pneumatic daisy-chaining tool.
3. Check machine zeroing.
4. Perform daisy-chain operation on posts designated by the wire-wrap machine/test tape 1.
5. Upon completion of the daisy-chain operation, use an ohm meter and verify that continuity exists between the daisy-chain wire and the daisy-chained posts. The last operation acts as a check on the validity of the entire test sequence.
6. Replace the daisy-chain N/C tape with the "test-continuity" tape.
7. Under the control of the second test tape, perform the wire-wrap validation as described in the previous verification note.

3.2 Current Modifications

A verification step which would precede the above-described daisy-chain and net-verification process is currently being programmed. This extra process consists of the generation of an N/C tape containing the location of all the unused (unwrapped) pins in a column-sorted sequence. The wire-wrap machine will sequentially point to all unwrapped pins designated by the N/C tape. The operator would visually verify that they were indeed unwrapped. While the machine is scanning the columns, the operator would verify that wrapped pins were indeed wrapped. The purpose of this procedure will be to increase the probability that the nets are correct.

4. WIRING OPTIONS

The following three wiring options are available and can be activated during the "header data input" portion of the WRAPS program.

1. Square-route
2. Z-route
3. Busing

The square-routing option (fig. 10) provides enough extra wire to allow a wrapped wire to be hand-routed into X or Y channels. All that is required to activate this routing option is to specify square-routing during header data input.

The Z-routing option (fig. 11) provides enough extra wire to allow a wrapped wire to be hand-routed into two X-channels and one Y-channel. All that is required to activate this routing option is to specify Z-routing during header data input.

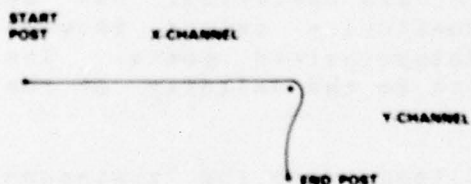


Figure 10. Square-routing.

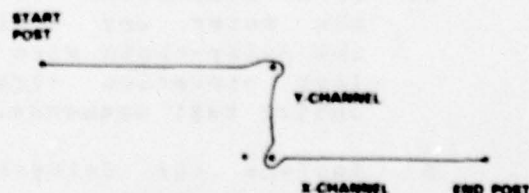


Figure 11. Z-routing.

The busing option is used to wire-wrap the backplanes of card cages. What makes card-cage backplanes different from other wire-wrap planes is the repetitive nature of the required wiring. In other words, a given signal will be wired in a

repeatable fashion across the backplane. The busing option allows a set of "bus wires" to be defined and allows a set of "places" to be defined. A set of "bus wires" will be wire-wrapped to every defined "place." To activate the busing option, all that is required is a "yes" response to the computer query "DO YOU WANT TO BUS ANY WIRES?"

After the "bus wires" and "places" are defined, the computer takes this information and generates a wire-list, which in turn can be processed by WRAPS to create an N/C wire-wrap tape. The advantage of using the bus option over normal wire-list input is the smaller possibility of errors during data input.

5. CONCLUDING REMARKS

The information given in this report, along with that given in the appendices, should allow the reader to understand the procedures necessary to work the HDL semiautomatic wire-wrap machine.

APPENDIX A.--COMPUTER START-UP PROCEDURES

The information contained in this appendix is in an instructional format and applies to the wire-wrap facility found at Harry Diamond Laboratories. A similar set of instructions can easily be created to reflect the requirements of other wire-wrap facilities.

The computer is the Hewlett Packard 2100A minicomputer and includes the following peripherals:

1. HP 2767A line printer,
2. HP 2600A CRT/keyboard,
3. HP 7900A disc drive,
4. HP 2748B tape reader,
5. HP 2895B tape punch,
6. HP 2155A input/output (I/O) extender, and
7. Keytronics M-9 optical character reader.

Before computer start-up, switch on power to all the above items.

The following instructions pertain to computer system initiation.

1. Power on the computer and peripherals.
2. Wait until the READY lamp on the line printer turns on before continuing.
3. Toggle MASTER CLEAR on the line printer.
4. Toggle ON LINE on the line printer.
5. Open the disc drive panel and insert the DOSIII-B disc. Close the disc drive panel and turn the LOAD/UNLOAD switch to LOAD.
6. Press the LOAD button on the tape reader.
7. Load the DOSIII boot tape into the tape reader (feeding from left to right, with the tape feed holes toward the tape reader).
8. Press the READ button on the tape reader.

The following instructions pertain to three rows of push buttons on the front panel of the computer (fig. A-1). The first row is called the display register and the push buttons

APPENDIX A

are numbered from 0 to 15. The remaining rows contain push buttons to indicate the various modes of ongoing computer operations.

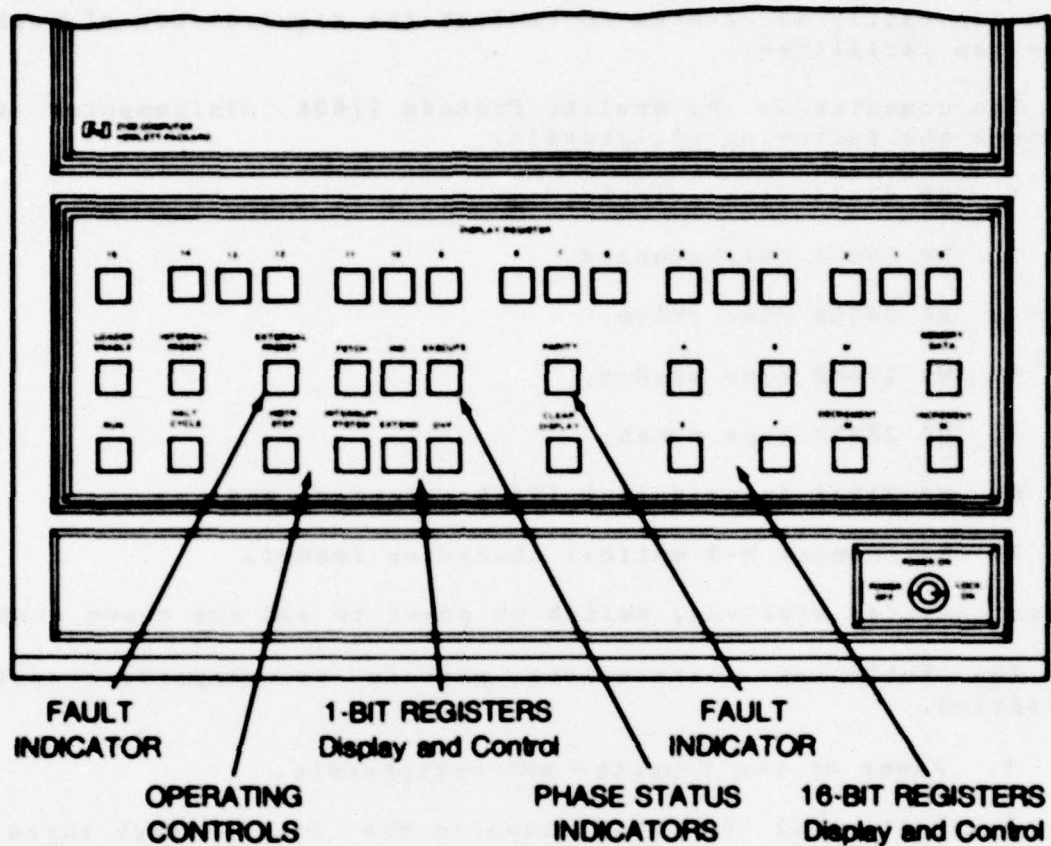


Figure A-1. Computer front panel.

1. Press button P.

2. Press button CLEAR DISPLAY.

3. At the display register, press and light the following buttons (X = ON, [X] = OFF).

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
X	[X]	X	[X]	X	X	X	X	X	X	[X]	[X]	[X]	[X]	[X]	[X]
0	5				7			7			0				0

(The push buttons display an octal 057700 number code.)

4. Press button S.

5. Press button CLEAR DISPLAY.

6. Press button EXTERNAL PRESET.

7. Press button INTERNAL PRESET.

8. Press button LOADER ENABLE.

9. Press button RUN.

If the previous series of instructions is performed correctly, the computer's HALT button will light and the display register will light the following push buttons (X = ON, [X] = OFF).

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
X	[X]	[X]	[X]	[X]	X	[X]	[X]	[X]	[X]	X	X	X	X	X	X

1		0			2			0			7			7	
---	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--

The octal 102077 code indicates that the boot tape is properly loaded and computer start-up may proceed.

10. Press button P.

11. Press button CLEAR REGISTER.

12. At the display register, press and light the following push buttons (X = ON, [X] = OFF).

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
[X]	[X]	[X]	[X]	[X]	[X]	[X]	[X]	[X]	[X]	[X]	[X]	[X]	[X]	X	[X]

0		0			0			0			0			2	
---	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--

(The push buttons display an octal 000002 code.)

13. Press button S.

14. Press button CLEAR REGISTER.

15. At the display register, press and light the following push buttons (X = ON, [X] = OFF).

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
[X]	[X]	[X]	[X]	[X]	[X]	[X]	[X]	[X]	[X]	[X]	X	[X]	[X]	[X]	X

0		0			0			0			2			1	
---	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--

(The push buttons display an octal 000021 code.)

16. Press button EXTERNAL PRESET.

17. Press button INTERNAL PRESET.

18. Press button RUN.

APPENDIX A

If the previous series of instructions is performed correctly, the computer's HALT button will light and the display register will light the following push buttons (X = ON, [X] = OFF).

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
X	[X]	[X]	[X]	[X]	X	[X]	[X]	[X]	[X]	X	X	X	X	X	X
1		0			2			0			7			7	

(The push buttons display an octal 102077 code.)

19. Press button P.

20. Press button CLEAR DISPLAY.

21. At the display register, press and light the following push buttons (X = ON, [X] = OFF).

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
[X]	[X]	[X]	[X]	[X]	[X]	[X]	[X]	[X]	X	[X]	[X]	[X]	[X]	[X]	[X]
0		0			0			1			0			0	

(The push buttons form an octal 000100 code.)

22. Press button S.

23. Press button CLEAR DISPLAY.

24. Press button EXTERNAL PRESET.

25. Press button INTERNAL PRESET.

26. Press button RUN.

If the previous instructions are performed correctly, the computer will remain in the RUN mode and will request DATE information at the CRT terminal.

The following instructions are typed on the CRT terminal and are the last steps in preparing the computer for the first job.

27. Computer requests:

INPUT: DATE XXXXXXXX

User responds:

:DATE,05.FEB.79 CrLf

(Note: CrLf--carriage return line feed)

28. Computer responds:

```
SUBCHAN = 01  
LBL = SYSTEM  
@  
[X]
```

(Note: [X] is the terminal's blinking cursor)

User responds:

```
:JOB      CrLf
```

Computer responds:

```
JOB      05.FEB.79  
@  
[X]
```

At this time the computer is in the standby mode and is ready to accept a job.

APPENDIX B.--ASSEMBLING AND LOADING AN XYDIM PROGRAM

The information contained in this appendix is in an instructional format and applies to the wire-wrap facility found at Harry Diamond Laboratories. A similar set of instructions can easily be created to reflect the requirements of other wire-wrap facilities.

The XYDIM program is the FORTRAN subroutine used to generate X,Y coordinates of a post location. Assuming the subroutine is already written, the method given in this appendix can be used to load and assemble XYDIM and WRAPS. (WRAPS is the main wire-wrap program that calls XYDIM.)

The following instructions result in a listing of computer job-control commands that begin and end the new XYDIM subroutine.

User types

:JOB CrLf

User types

:LIST,S,6,XYDATA CrLf

(Note: XYDATA (fig. B-1) is a set of job control commands into which an XYDIM subroutine is inserted; CrLf--carriage return line feed.)

```
0001 :PU,WRAPS,PART1,PXYDM
0002 :RP
0003 :PR,FTN4,5,1,99
0004 FTN4,L
0005 SUBROUTINE XYDIM
0006 REAL LWX,LWY
0007 DIMENSION IHOL(2),KCD(6)
0008 COMMON NIN,NOT,IPR,IPAGE,LCNT
0009 COMMON
0010 ICUST(20),IWL(6),IPEV,GRID,IAWG,WLMN,STPLT,ISW1,
0011 *ISWSL(5),LWX,HIX,LWY,HIY,INCRD(80),NET(7),NPIN(7),OLDX,
0012 OLDY,
0013 *XDIM,YDIM,SIX,SIY,S2X,S2Y,PIX,PIY,WPLT,IBZ,ISW12,INST
0012 100 RETURN
0013 END
0014 ENDS
0015 :ST,P,PXYDM
0016 :CL
0017 :PR,LOADP,2,1
0018 PWPAP,RMN1,PXYDM
0019 /E
0020 :PU,PXYDM
0021 :TY
```

**** LIST END ****

Figure B-1. Listing of XYDATA control statements.

Instead of typing both the XYDIM subroutine and the corresponding job-control statements, the system line editor is used. The line editor allows the user to insert the XYDIM subroutine between the appropriate control statements, thus localizing any typing errors to the subroutine.

The listing displayed in figure B-1 includes a column of line numbers along the left margin. The XYDIM subroutine is inserted between line numbers 11 and 12 by the use of the system editor. The following series of instructions puts the computer into the editing mode and allows the insertion of the XYDIM subroutine.

1. Type

```
:EDIT,XYDATA,1,(new file name) CrLf
```

(new file name) is the disc file where the XYDIM subroutine and job-control statements are to be stored. New file name has a maximum of five alphanumeric characters.

2. Type

```
/INSERT,11 CrLf
```

This command prompts the system for user input.

3. Type in the new subroutine starting with data statements.

4. Type

```
/END CrLf
```

"/END" terminates the editing session and stores the new XYDIM under (new file name).

5. Type

```
:LIST,S,6,(new file name) CrLf
```

The new XYDIM subroutine and job-control statements are listed on the system line printer. The printed column of line numbers along the left margin must be referenced if further editing is required.

6. If no editing is required, go to step 7.

Type

```
:EDIT,(new file name),1 CrLf
```

Perform required editing and type

```
/END CrLf
```

7. Program assembly involves the linking up of the new XYDIM subroutine with the main program. The easiest method for achieving the linkup is to run the new XYDIM and job-control statements in BATCH. The following series of instructions results in the proper linkup.

Type

```
:DUMP,4,(new file name) CrLf
```

This command transfers the entire XYDIM and job-control statements onto a paper tape. Remove the paper tape and load the tape into the photo reader (feedholes away from operator).

Type

```
:SS CrLf
:UD,SYSTEM,1 CrLf
:BATCH,5 CrLf
```

At this time the new XYDIM subroutine is loaded and, if no compile errors occur, the "NO ERRORS" message is displayed on the CRT. When the entire program is linked and assembled, the following series of statements is displayed on the CRT.

```
LOADR COMPLETE
:PU,RXYDM
RXYDM
XTY
@
[X]
```

The WRAPS and XYDIM programs are linked and ready to run. The entire start, load, and link process requires approximately 1.5 hours.

APPENDIX C.--SETUP AND USE OF KEYTRONICS WAND IN WIRE-WRAP

The information contained in this appendix is in an instructional format and applies to the wire-wrap facility found at Harry Diamond Laboratories. A similar set of instructions can easily be created to reflect the requirements of other wire-wrap facilities.

The Keytronics wand is a hand-held optical character reader capable of scanning special pretyped information and transferring this information to a computer.

The Keytronics wand is wired in parallel to the CRT terminal. The terminal is used to override the wand in situations where a scanned character is unrecognizable.

The Keytronics wand offers high-speed transfer of data to a computer without the errors normally associated with CRT terminal input.

The pretyped information must be

1. typed in OCRA (optical character recognition version A) font,
2. double spaced, and
3. ten characters per inch.

When the Keytronics wand is used to scan wire-list data, the following format is used:

XXXXXXXX XXXXXXXX

XXXXXXXX XXXXXXXX

The "X's" designate character placement for the signal mnemonic and post location mnemonic, each with a maximum of seven alphanumeric symbols. The second row designates the placement of the next signal mnemonic and post location mnemonic. The remaining data follow in the same fashion.

The next series of instructions pertains to setting up the Keytronics wand.

1. Turn BAUD SELECT to Code 5.
2. Turn thumbwheel switches to 11 on channels 1 and 2.
3. Press and set special mode switch 5. Press ENTR switch.
4. Check PRINT QUALITY dials and verify the 1 to 4 setting. (Adjust if required.)

APPENDIX C

5. Plug wand into channel 1.
6. If the computer is ready to accept scanned data, the user can start at this time.

APPENDIX D.--NUMERICAL CONTROL TAPE PUNCHING

The information contained in this appendix is in an instructional format and applies to the wire-wrap facility found at Harry Diamond Laboratories. A similar set of instructions can easily be created to reflect the requirements of other wire-wrap facilities.

After wire-list data are processed by parts 1 and 2 of the WRAPS program, the numerical control (N/C) tape is ready to be punched. This N/C tape will contain all the information required by the wire-wrap machine for wiring a backplane.

The following series of instructions generates the N/C tape.

1. Generate a 2-ft-long leader tape by pressing the FEED HOLES switch on the system punch.
2. Type the following in response to the computer message "PUNCH N/C TAPE?".

Yes CrLf

(Note: CrLf--carriage return linefeed)

3. When the system punch is finished generating the N/C tape, add a 2-ft-long leader to the end of the tape.

If at any time the paper tape supply runs out before the N/C tape generation is complete, then the following recovery procedure must be used.

1. Reload a new spool of paper tape and add a 2-ft leader as before.

2. Type

:UP,4 CrLf

:RUN,WRAPS CrLf

3. Type

Yes CrLf

in response to the computer message

PUNCH N/C TAPE?

4. After the new N/C tape is punched, add a final 2-ft leader.

5. Spool the paper tape and proceed to the actual wire-wrapping.

APPENDIX E.--NUMERICAL CONTROL WIRE-WRAP MACHINE SETUP

The information contained in this appendix is in an instructional format and applies to the wire-wrap facility found at Harry Diamond Laboratories. A similar set of instructions can easily be created to reflect the requirements of other wire-wrap facilities.

E-1. POWER-UP PROCEDURE

This procedure describes how the wire-wrap system at HDL is started for performing an entirely new job.

1. See procedure (section E-3) to thread wire into Gardner-Denver (G-D) stripper if wire size change is required. Verify that power to G-D stripper is off before going to step 2.
2. Mount N/C tape into Remex tape reader as follows.
 - a. At console, turn power switch OFF.
 - b. At Remex tape reader, set RUN/LOAD switch to LOAD.
 - c. Set SPOOL/LOOP switch to SPOOL.
 - d. Set Remex power switch to ON (power controlled via console).
 - e. Set mode switch to SET ZERO.
 - f. Set ASCII/EIA to ASCII.
 - g. Set REMOTE/LOCAL to REMOTE.
 - h. Set X,Y coordinate switches to 00000.
 - i. Load paper tape feeding the leader from right to left following the black stripe on the front panel.
 - j. Position the paper tape over the reader before the writing information begins; this position may be after identification information.
3. Set up the wire stripper as follows:
 - a. Set leftmost counter to 0000001; check by pushing red button.
 - b. Set rightmost counter to 000.
 - c. Set CUT CLAMP, STRIP, and EJECT down to AUTO.
 - d. Set N/C/OFF to N/C.

- f. Turn power off.
- 4. Set up the console controls as follows.
 - a. FAST/SLOW/CREEP to FAST.
 - b. WIRE LENGTH/BIN NO. to WIRE LENGTH.

The following switches are spring loaded and require no settings:

REZERO, BACK-UP, UP-DOWN, and L/R.

- 5. Turn on power as follows (read following section before executing).
 - a. Turn on air pressure in Machine Shop (green valve).
 - b. Turn on bench power.
 - c. Turn on console power.
 - d. Activate red emergency bar immediately upon turning on console power.
 - e. Press REZERO.
 - f. Turn on both panel lights.
- 6. Mount wire-wrap panel, carefully square panel and check depth clearance, lock depth with eight screws, and check clearance over entire board--beware of board bowing. Clearance should be 0.050 to 0.100 in.
- 7. Zero on origin pin.
 - a. Set MODE SWITCH to ZERO SET.
 - b. Set SPEED CONTROL to SLOW.
 - c. Move pointer to desired origin pin with UP-DOWN and L-R controls.
 - d. Move pointer to final position in CREEP speed.
 - e. Hit safety bar (red emergency bar).
 - f. Set speed to FAST.
 - g. Press REZERO.

- h. Hit safety bar again.
- 1. Press REZERO once more.
- 8. Press RUN/LOAD to RUN on Remex tape reader.
- 9. Set MODE SWITCH to AUTO on Remex tape reader.
- 10. Turn on stripper power switch.
- 11. Index tape using gun advance.

You are now ready to wrap.

E-2. RESTART FROM ONGOING JOB

- 1. Set MODE SELECT on Remex to ZERO SET.
- 2. Turn on bench power and air pressure.
- 3. Turn console power on, hit safety bar, and press REZERO.
Random readouts come up.
- 4. Turn on stripper power and both panel illumination lights.
- 5. Rezero on to origin pin of board as follows:
 - a. Set speed control to SLOW.
 - b. Move pointer to desired origin pin with UP-DOWN and L-R toggles.
 - c. Move pointer to final position in CREEP speed.
 - d. Hit safety bar.
 - e. Set speed to FAST.
 - f. Press REZERO.
 - g. Hit safety bar again.
 - h. Press REZERO again.
- 6. To locate proper block in tape reader, do the following.
 - a. Set MODE SELECT to TAPE SCAN.
 - b. Use REVERSE-FORWARD toggles to find the last completed tape sequence number.

APPENDIX E

- c. Turn mode switch to AUTO.
- d. Index with wire-wrap gun.
- e. Check position and wire length, if any, with printout.
- f. Continue wiring.

E-3. PROCEDURE TO THREAD WIRE INTO GARDNER-DENVER STRIPPER

- 1. Remove old wire from stripper as follows.
 - a. Slide off plastic OSHA (Occupational Safety and Health Administration) safety guard.
 - b. Turn off power to entire stripper--note that de-reel motor has a separate power plug.
 - c. Pull out old wire.
- 2. Thread new wire as follows:
 - a. Mount new roll of wire.
 - b. Pass new wire through dereeler wheels.
 - c. Pass wire through hole directly beneath wheels.
 - d. Pass wire through folded wire feeder.
 - e. Feed wire through splice-detector tube.
 - f. Check that stripper switches are set as follows:

CUT, CLAMP, STRIP, and EJECT are all down,
N/C is up, and
SINGLE CYCLE is up.
 - g. Turn on stripper power.
 - h. Feed wire through nozzle.
 - i. Press jog button. Wire should now be threaded; if not, pull out wire and try again.
 - j. Reinstall OSHA plastic guard.

E-4. MANUAL PROCEDURE FOR "GO TO" POSITION

1. If machine is already powered up and an origin point has been chosen, the following steps are followed.
 - a. Set REMOTE-LOCAL to LOCAL.
 - b. Set MODE SWITCH to AUTO or TAPE SCAN.
 - c. Set thumbwheel switches to desired X; toggle GO TO X.
 - d. Set thumbwheel switches to desired Y; toggle GO TO Y.

If reference was not set, then perform the zero-origin pin procedure (step 7 of power-up procedure, sect. E-1).

2. If machine is not powered up, execute steps 4, 5, and 7 of power-up procedure.

E-5. RECOUP FROM BROKEN WIRE

1. If the wire is broken while the first end is being wrapped, remove the wire and press CYCLE on the stripper. A new wire will be stripped and you are already in the correct position to wire.
2. If the wire is damaged while the second end is being wrapped, then
 - a. remove the second end of the wire,
 - b. toggle the BACKUP switch,
 - c. remove the first end of the wire, and
 - d. press CYCLE on stripper and rewrap from this point.

E-6. RECOUP FROM SAFETY BAR ACTIVATION

1. Set MODE SELECT to ZERO SET.
2. Hit REZERO to shut off alarm.
3. Perform REZERO (sect. E-1, step 7) procedure.
4. Set MODE SELECT to AUTO.
5. Toggle BACKUP switch.
6. Advance machine by wire-wrap gun. Check for correct position by tape sequence number and position location; continue.

APPENDIX E

E-7. TAPE SCAN TO DESIRED TAPE SEQUENCE NUMBER

1. Set MODE SWITCH to TAPE SCAN.
2. Set REMOTE-LOCAL to REMOTE.
3. Move tape through reader by ADVANCE button or by TAPE SCAN toggle (REVERSE or FORWARD).
4. Stop on the tape sequence number previous to the one you desire to execute.
5. Set MODE SWITCH to AUTO.
6. Advance machine with wire-wrap gun.

E-8. TURN-OFF PROCEDURE

The wire-wrap machine is turned off as follows:

1. Note (by writing down) the last sequence number you completed.
2. Press REZERO button on left console.
3. Turn off stripper power.
4. Turn off console power.
5. Turn off bench power.
6. Turn off air in Machine Shop.

APPENDIX F.--HEWLETT-PACKARD (HP 2100A) WIRE-WRAP SOFTWARE

F-1. INTRODUCTION

The information contained in this appendix is in an instructional format and applies to the wire-wrap facility found at the Harry Diamond Laboratories. A similar set of instructions can easily be created to reflect the requirements of other wire-wrap facilities.

The software required to convert a conventional wire list to the appropriate codes to drive the numerically controlled (N/C) controller associated with the Computerwrap wire terminating system has been written in FORTRAN IV for the HP 2100A minicomputer. The software consists of three major divisions:

- a. an input section which receives the wire list data, stores it in a disc file, and provides for editing, listing, etc.
- b. a computational section which converts alphanumeric location mnemonics to post locations in inches, computes route points, does error checking, performs various other "housekeeping" chores, and punches the paper tapes required for verification of the wiring, and
- c. a sorting and conversion section which punches the paper tape for wiring the panel.

F-2. COMPUTATIONS

The X,Y coordinates (in inches) of the post locations are calculated based on the post mnemonics, using the subroutine XYDIM. The locations of the beginning and ending posts of each net are saved for the verification section. The level assignment is made for each wire, always assigning the first wire in each net to the first level. The wire length is calculated based on the routing selection, minimum wire length, strip length, etc. Error checks are made to ensure that the locations computed by XYDIM are within limits, that no nets consist of a single post, and that no two consecutive posts have the same location.

F-3. SORTING AND CONVERSION

The wires are sorted by level and by wire lengths within a level. The sorted data are then formatted and punched on paper tape.

For each post there is a record on the paper tape consisting of the codes below:

M d N d X d Y d D d R d T d B d S E H *

APPENDIX F

- The d code represents a string of digits, and the asterisk represents an end-of-block character.
- M codes are the record sequence numbers, starting with M0 for the initialization record, and incrementing by 1 throughout the job (maximum 9999).
- N codes are the wire sequence numbers, starting with N0 for the initialization record, and incrementing by 1 at the start of each new wire (maximum 9999). The wire sequence number is displayed on the Computerwrap reader.
- X codes are the X coordinates in inches, varying from -99.999 to +99.999 in.
- Y codes are the Y coordinates in inches, varying from -99.999 to +99.999 in.
- D codes are direction codes lighting four direction indicators singly or in combination to warn the operator about the next machine movement. The D codes are as follows:

D1	west lamp
D2	north lamp
D4	east lamp
D10	south lamp
D3	northwest lamp
D6	northeast lamp
D11	southwest lamp
D14	southeast lamp
D0	all lamps off

- R codes are spares with no designated use at this time.
- T codes allow proper identification of twisted wire pairs by lighting appropriate lamps. The T0 and T7 codes light B and W lamps which correspond to black and white twisted wires. The T1 code turns off B, W, S, and E lamps to indicate a route position for square and Z routing. (S lamp signifies the start post; E lamp signifies the end post.)
- B codes are the wire lengths in tenths of an inch. This code appears only in records of start posts (maximum 999 or 99.9 in.).

- S codes are the start codes; an S lamp is lit for the beginning post of new wires.
- E codes are the end codes; an E lamp is lit for the ending post of new wires.
- H code sounds a horn.

Punched N/C tape information other than post data includes user identification codes and system initialization codes. Identification codes are punched ASCII characters representing user name and job title. Following identification codes are the A code and the system initialization code. The A code terminates a tape rewind code, and the system initialization code primes the system to receive regular post data. The rewind termination and system initialization codes are

A<PMPBPX50Y50HDOROT1*

* = end of block, and

A = end of rewind code.

After all post data blocks are processed, a rewind code consisting of "AA*" completes the wire-wrapping process by rewinding the N/C tape.

During the wire-wrapping process the operator may be reassured that the ongoing wire-wrapping is correct by using computer-generated wire lists. These lists reflect the various states of the wire-wrap system. Listed information includes the following.

Record sequence number

Wire sequence number

Alphanumeric post mnemonics (from-to)

Wire length (in inches)

Route point or wire level

F-4. VERIFICATION

The verification tapes described in the body of this report are produced as follows.

The locations of the posts to be wired are computed in Part I of the software program, and those of the first and last posts of each net are stored until all have been calculated. Then for each single-wire net (pseudonet), the post which has the smallest Y-value is selected as the beginning post of the net, and the

APPENDIX F

other, the end. Then the beginning locations are sorted on X. Then the locations of this sorted selection of posts are punched on a tape, which is used to form the daisy chain shown in figure 9 in the main body of the report. Then the locations of the corresponding end posts are punched on paper tape in the reverse order. Thus, for the first test tape, the wire-wrap N/C pointer will point to the beginning of each pseudonet proceeding from left to right as the operator forms the daisy-chain. Then for the second test tape the head will point to the end of each pseudonet starting with the last net in the chain and proceeding from net to net until the end of the first net is reached. The format of these tapes is identical to the tape produced in Part 2.

If the wire-list is not entered in order by net, then a sort is required to put all posts in the same net in sequence. The sort routine can process 5120 elements, so the number of posts, which is equal to the number of entries in the wire-list, is limited to 5120.

If the wire-list is in order by net, then the only sort required is that in Part 2, which is a sort by wire, so the number of wires is limited to 5120. The number of wires, in terms of nets, is

$$X = \sum_{i=1}^m (n_i - 1),$$

where

- X = number of wires,
- m = number of nets, and
- n_i = number of posts in net i.

This section ends the description on how verification tapes are generated. A more thorough description of how the verification proceeds is found in the main body of this report.

DISTRIBUTION

ADMINISTRATOR
DEFENSE DOCUMENTATION CENTER
ATTN DDC-TCA (12 COPIES)
CAMERON STATION, BUILDING 5
ALEXANDRIA, VA 22314

COMMANDER
US ARMY RSCH & STD GP (EUR)
ATTN LTC JAMES M. KENNEDY, JR.
CHIEF, PHYSICS & MATH BRANCH
FPO NEW YORK 09510

COMMANDER
US ARMY MATERIEL DEVELOPMENT &
READINESS COMMAND
ATTN DRXAM-TL, HQ TECH LIBRARY
ATTN DRCMT, F. MICHEL/E. GARDNER (2 COPIES)
5001 EISENHOWER AVENUE
ALEXANDRIA, VA 22333

COMMANDER
US ARMY MISSILE & MUNITIONS
CENTER & SCHOOL
ATTN ATSK-CTD-F
REDSTONE ARSENAL, AL 35809

DIRECTOR
US ARMY MATERIEL SYSTEMS ANALYSIS ACTIVITY
ATTN DRXSY-MP
ABERDEEN PROVING GROUND, MD 21005

DIRECTOR
US ARMY BALLISTIC RESEARCH LABORATORY
ATTN DRDAR-TSB-S (STINFO)
ABERDEEN PROVING GROUND, MD 21005

TELEDYNE BROWN ENGINEERING
CUMMINGS RESEARCH PARK
ATTN DR. MELVIN L. PRICE, MS-44
HUNTSVILLE, AL 35807

ENGINEERING SOCIETIES LIBRARY
345 EAST 47TH STREET
ATTN ACQUISITIONS DEPARTMENT
NEW YORK, NY 10017

COMMANDER
NAVAIR
ATTN R. A. RETTA
CODE AIR 52022
WASHINGTON, DC 20361

PROJECT MANAGER
AMMUNITION PRODUCTION BASE
MODERNIZATION AND EXPANSION
ATTN DRCPM-PBM-PB, DAROLD L. GRIFFIN
DOVER, NJ 07801

IBEA
US ARMY INDUSTRIA BASE
ENGINEERING ACTIVITY
ATTN DRXIB-MT, J. CASTENS
ATTN DRXIB-MT, C. MCBURNIE
ROCK ISLAND, IL 61299

COMMANDER
US ARMY MATERIALS & MECHANICS
RESEARCH CENTER
ATTN DRXMR-PT, R. FARROW
ATTN DRXMR-PT, F. STENTON
ATTN DRXMR-PT, P. ROULSTON
WATERTOWN, MA 02172

COMMANDER
ERADCOM
ATTN DELET-DP, J. A. KEY
FORT MONMOUTH, NJ 07703

COMMANDER
US ARMY AVIATION SYSTEMS R&D COMMAND
ATTN DRDAV-EXT, R. VOLLMER
12TH & SPRUCE STREETS
ST LOUIS, MO 63166

COMMANDER
US ARMY MISSILE R&D COMMAND
ATTN DRDMI-EAT, W. K. PATTERSON
REDSTONE ARSENAL, AL 35809

US ARMY ELECTRONICS RESEARCH
& DEVELOPMENT COMMAND
ATTN WISEMAN, ROBERT S., DR., DRDEL-CT
ATTN O'ROURKE, CALVIN, (RDEL-BC)

HARRY DIAMOND LABORATORIES
ATTN 00100, COMMANDER/TECHNICAL DIR/TSO
ATTN CHIEF, DIV 10000
ATTN CHIEF, DIV 20000
ATTN CHIEF, DIV 30000
ATTN CHIEF, DIV 40000
ATTN RECORD COPY, 81200
ATTN HDL LIBRARY, 81100 (3 COPIES)
ATTN HDL LIBRARY, 81100 (WOODBIDGE)
ATTN CHAIRMAN, EDITORIAL COMMITTEE
ATTN TECHNICAL REPORTS BRANCH, 81300
ATTN POPE, G., 00210
ATTN HOKE, J., 00210
ATTN KAISER, Q., 13500
ATTN GOODMAN, R., 34400
ATTN FURLANI, J., 48100
ATTN LANHAM, C., 00210
ATTN HOFF, R. S., 47000
ATTN LEE, A., 48200 (3 COPIES)
ATTN HINE, R., 00250 (3 COPIES)